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ABSTRACT

Longitudinal research is needed to investigate the effect of science teacher education programs. The impact of the program may not be evident until two or three years after the experience. This type of research can also assist in planning interventions and professional growth opportunities. Universities often do not take responsibility for tracking teacher graduates and determining the effectiveness of their training. To address the dearth of data, this study tracked graduates who received an inquiry course intervention, one to three years after completing the course. One of the goals was to track these teachers as they began teaching. If their responses to the course could be understood and if they use the inquiry methods advocated in the course in a way that promotes scientific literacy, other universities might be inclined to implement similar programs. Among other findings are that the use of inquiry and other experiences may not be detectable until after four years of teaching when the teacher has become more comfortable in the classroom. (Contains 16 references.) (Author/MVL)

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Views of Science Teachers One-Three Years After a Preservice Inquiry-Based Research Course

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VIEWS OF SCIENCE TEACHERS ONE-THREE YEARS AFTER A PRE-SERVICE INQUIRY-BASED RESEARCH COURSE

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The National Science Education Standards (National Research Council, 1996) and the Benchmarks for Science Literacy (AAAS, 1993) indicate the importance of science curriculum reform because of the need for all Americans to become scientifically literate. Project 2061 was started in 1985 by the American Association for the Advancement of Science (AAAS) in order to reform K-12 science, math, and technology education. The significance of the name Project 2061 is that Halley's comet was visible in 1985 when the project was started and the year 2061 is when the comet will return. It is the hope of the AAAS that all Americans will be scientifically literate by the year 2061.

The need for science education reform has been motivated by other factors than "liberating the human intellect" alone. For example, there is a shortage of qualified people to fill professional science positions including K-12 educators. Education studies in the United States conducted in the 1980's were initiated because of various public concerns. These concerns included economic decline and educational shortcomings such as low test scores and a low ranking in comparison to other advanced nations in students' knowledge of science and mathematics. According to some of the reports, the economic decline has been attributed to education failures (AAAS, 1990).

Science for all Americans (AAAS, 1990) states the belief that the science literate person:

> Is aware that science, mathematics, and technology are interdependent human enterprises with strengths and limitations; understands key concepts and principles of science; is familiar with the natural world and recognizes both its diversity and unity; and uses

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> scientific knowledge and scientific ways of thinking for individual and social purposes. (p. xvii)

Schwartz, Lederman, and Crawford (2000) state that scientific literacy includes knowledge of scientific concepts (facts), scientific inquiry (processes), and the nature (values and assumptions) of science. They and other researchers (Melear, Goodlaxson, Warne, & Hickok, 2000; Duggan-Haas, 1998a) feel that the failure of Americans to reach scientific literacy can be attributed in part to a deficiency in learning by scientific inquiry and about the nature of science. Students and their teachers who have not had adequate experiences in conducting scientific inquiry may view science as nothing more than isolated facts that are difficult to apply to the real world.

Science literacy can only be accomplished by improving the training of our future K-12 science educators. Teachers must gain the necessary knowledge and skills through "authentic scientific inquiry experiences" provided throughout science teacher education (National Research Council, 1996). This can include an "immersion into the culture" of science by completing an undergraduate research experience within a course designed specifically for that purpose (Melear, et al., 2000). This study qualitatively examines the longitudinal effects of one such course offered at the University of Tennessee, Knoxville. This type of research is important because the results can be used to improve the quality of science teacher education.

Relevant Research/Theory Concerning Preservice Science Teachers' Research Experiences

In order to understand how to improve science education and scientific literacy an important place to start is to study how science teachers are prepared. The Salish I Research Project (Duggan-Haas, 1998a and Simmons, Emory, Carter, Coker, Finnegan, Crockett, Richardson, Yager, Craven, Tillotson, Brunkhorst, Twiest, Hossain, Gallagher, Duggan-Haas, Parker, Cajas, Alshannag, McGlamery, Krockover, Adams, Spector, LaPorta, James, Rearden, & Labuda, 1999) studied the entire system of science teacher preparation including the practices of

beginning secondary science and math teachers. Salish I was conducted by a national research collaborative which extended over a three-year period. Participants came from nine university research sites. Several findings of the Salish I study have relevance to this research study. One important finding was that students preparing to be science teachers experience a clash between the culture of a science education classroom and a pure science classroom. Another finding was that there is a lack of appropriate research experiences provided for science education students in universities.

Dichotomy of Two Cultures

The Salish I study showed that there is a lack of coherence between the content area training by scientists and the teacher education course work by science educators within the science teacher education programs studied (Duggan-Haas, 1998b). The culture of the typical college science classroom is one in which the scientist instructor lectures, promotes competition and discourages collaboration. The culture of the science/teacher educator classroom requires collaboration and discourages competition in order to create a community of learners. Scientists within a college often do not see themselves as part of the process of educating scientifically literate citizens. Their courses are often structured to weed out students and can turn away potentially good candidates for teaching. Duggan-Haas (1998b) presents several possibilities to improve college teaching including, recognizing the difference in the two cultures, recognizing that scientists are teacher educators and they must be responsible for helping improve the situation, and encouraging potential teachers by structuring the courses for learning rather than selecting and weeding out.

Lack of Appropriate Research Experiences for Science Educators

Based on findings of the Salish I study, Duggan-Haas (1998a) stresses the importance that pre-service science teachers (those that are training to be teachers) can benefit from research experiences. Teachers who completed an undergraduate research experience (RE) had much better understandings of the nature and processes of science than teachers who had not had the experience. "The RE seems to change the world view of those who complete it. . . . . The research experience can trigger an epiphany about the nature of science" (p. 6). However, there are problems with the way that most colleges structure REs in science. They are designed for students who wish to become researchers in a particular field of science, not for preparing students to teach. The RE often leads to a specialty in an obscure area of science that cannot be easily adapted to the K-12 curriculum. Completing a RE can often be an "initiation into the culture of science" (p. 1); however, without proper guidance, teachers may inappropriately associate this affiliation with the style of teaching of the scientist in the science classes that they teach. This style, as discussed earlier, is predominantly exhibited by lectures, promoting competition, and discouraging collaboration.

REs can be structured to benefit teachers in the process of attaining scientific literacy in the following ways. "Make the experience an explicit model for teaching and learning and modify the experience so that it is more readily translatable to the secondary classroom" (Duggan-Haas, 1998a, p. 12). Investigations, which are adaptable to the K-12 curriculum, can be designed using the classroom as a research site "The nature of the eperience should be reflected on to help teacher candidates design parallel experiences for their own students" (Duggan-Haas, 1998a, p. 13). REs conducted in this manner can help pre-service teachers learn to be more

inquiry-based and student-centered in their teaching which are some of the attributes teachers need to help promote scientific literacy.

An Attempt to Provide an Appropriate RE for Science Educators

Melear, a K-12 science education professor at the University of Tennessee, Knoxville, determined that most of the students who apply to the College of Education to become future science teachers have never actually conducted any authentic science (2000). The courses which included laboratories that these students completed as part of a major in a particular area of science typically did not include inquiry experiences in which they were a part of designing and carrying out their own experiments. She, along with Hickok, subsequently initiated a course called "Teaching Science-Just Do It" ("Do It") within the science department at the University to help alleviate the problem. The course is structured to allow pre-service biology majors to have REs that are designed for teachers to experience inquiry. "Many teachers come to learning activities with preconceptions about teaching science. At a minimum, their own science learning experiences have defined teaching for them" (National Research Council, 1996, p. 67). Therefore, if a teacher has not experienced learning as an inquiry process, it will most likely never be initiated in the classroom.

The theoretical foundations that Melear (2000) used for designing this course included immersion, the apprenticeship model for instruction, social constructivism, and situated cognition. Immersion is an approach to "teaching for thinking" in which pre-service teachers are immersed in the culture of science by conducting scientific research for a prolonged period in a lab. "Science can be considered as a culture, which can be learned best in the environment of members of that culture" (Melear, 2000, p. 7). The apprenticeship model for learning is the "acculturation into the world of the expert" (p. 8). The actual participation in the world of the

"expert" is an important criteria to allow the "expert" to transmit knowledge to the "novice." This knowledge changes with different contexts. Social constructivism and situated cognition can be used to describe how pre-service science teachers can "construct new knowledge through social interactions" (Melear, 2000, p. 8) Melear (2000) suggests that "placing learners . . . into the culture of science (science laboratories) will create an immersion experience in the culture, especially if the aspiring teachers are surrounded by persons who practice that culture, i.e., persons who 'speak the language'" (p. 9).

Research

Context, Questions, Goals, and Rationale

Context

Longitudinal research is needed to investigate the effect of science teacher education programs. "The impact of the program may not be evident until 2 or 3 years after the experience" (Adams & Krockover, 1999, pp. 968-969). This type of research can also assist in planning "interventions and professional growth opportunities" (p. 969). Universities often do not take responsibility for tracking teacher graduates and determining the effectiveness of their training. To address the dearth of data, this study tracked graduates who received the inquiry course intervention, one-three years after completing the course. One of our goals was to track these teachers as they began teaching (Melear, 2000). If we can understand their responses to the course and if they use the inquiry methods advocated in the course in a way that promotes scientific literacy, other universities might be inclined to implement similar programs.

The course has been offered six semesters at the University of Tennessee, since 1997. The pre-service science teachers were encouraged to take the course as part of their undergraduate program in biology. At the University of Tennessee, prospective teachers

complete a four-year undergraduate program within a major area and then complete a year-long teaching internship within a school near the university as part of a master's program. As stated earlier, the course is designed to provide research experiences for the biology teacher; therefore, all students who took the course had undergraduate biology concentrations.

Questions

Our objective was to identify how and if these teachers were influenced by the "Do It" course. Specific research questions included the following:

- Did the experiences the participants had with inquiry in the course help them understand how to teach by inquiry?
- Did the course help the participants understand the nature of science?
- How does the course compare to other courses the participants had in preparing them to teach?

Research Goals – A description of the qualitative philosophy of inquiry

In order to understand the meanings the course had for participants, a qualitative rather than quantitative approach was necessary. Studies in science education have traditionally "ignored the meanings that participants in a study bring to the experience rather that viewing these meanings as integral to the experience" (Simmons, et al., 1999, p. 932). Meanings are complex in that they are unique, shared, constantly changing, subjective, contextual, and created through interaction in our world. Qualitative research is "any systematic investigation that attempts to understand the meanings that things have for individuals from their own perspectives" (Singletary, 1994, p. 266). Whereas qualitative research is descriptive and collects data in the participants' own words, quantitative research is statistical and data is collected based on the researcher's predetermined agenda (Bogdan & Biklen, 1992).

Rationale

Individual interviews were conducted because they allowed the participants' perspectives to be expressed in their own words (Taylor & Bogdan, 1984). This method of qualitative research was appropriate for several reasons, including several issues related to time and the goals of the research. The first issue with time was that the first author did not observe the participants while they took the course. Therefore, asking them to describe the course personally, was an appropriate way to get at the meanings the course had for them.

Interviews were appropriate for the goals of the research as well. According to Taylor and Bogdan (1984), interviewing is well suited when "research interests are relatively clear and well-defined" (p. 80) and when the "researcher wants to illuminate subjective human experience" (p. 81). The goals of finding out the meanings of the "Do It" course were clear. Interviews are used when direct observations cannot be made. Patton (1990) suggests that feelings, thoughts, and intentions cannot be observed.

Methods

A qualitative study was chosen because the research questions suggested the use of such methods. Qualitative methods and analysis are emergent, meaning that the methods used to collect and analyze data can change throughout the study based upon what is discovered during the research. For example, questions on an interview guide can and should be changed after a study has begun, when issues emerge from the participant's feedback. Quantitative methods would require that questions asked of participants remain the same throughout the study.

Participants

Recruitment

Participants were recruited from a list of 13 students, who had taken the course in the Fall of '97, '98, or '99, and who were currently teaching. The students from the Fall of '97 were in their second year of teaching. The students from the Fall of '98 and '99 courses were in their first year of teaching. In order to recruit research candidates each was sent a letter by e-mail explaining the purposes of the study and asking them if they would be willing to participate. If there was no response to the e-mail letter, the same letter was mailed to their home address on. If there was no response to the mailed letter, the prospects were telephoned. Eight of the 13 possible candidates were contacted. The five that were not contacted had changed their mailing address since attending the university and did not respond to any e-mail attempts or phone calls (in two instances, a phone number was not available).

All eight candidates that were contacted agreed to be research participants. Only three out of the eight participants lived more than an hour out of the Knoxville, Tennessee area. Four of the participants were interviewed at the Tennessee Science Teachers Association (TSTA) conference between November 30-December 2, 2000 in Nashville, Tennessee. Two other participants were met at the University of Tennessee library for their interviews. One of the participants requested that the interview be held in her classroom after school. The final interview was conducted over the phone.

The number of participants for a study can vary; however, according to McCracken (1988), eight participants are an appropriate number to include in a qualitative study. A major factor in determining participant numbers is when information redundancy has been reached. For the purposes of this study eight were interviewed and data was examined to determine if a

level of redundancy was reached. This level is reached if no new information is found in consecutive interviews. If new information had been found, additional participants would have been solicited.

Finally, the instructor and co-creator of the "Do It" course, Dr. Leslie G. Hickok was contacted in April 2001 for an interview by the first author. He agreed to an interview to discuss the course. It was important to use him as a data source as well. Major questions asked of him were concerning his goals for the course, what he felt the students gained from the course, and how this course was structured differently from other science courses offered at the University of Tennessee.

Description of the Participants

As stated, all participants completed a year-long internship in teaching as part of the master's and certification requirements program at the University of Tennessee and were currently teaching in public high schools in Tennessee. Two of the research participants completed the "Do It" course in 1997, five in 1998, and one in 1999. Six participants were teaching biology as well as other courses, one was teaching physical science and chemistry, and one was teaching physical science and a basic introductory science course. Six participants were females and two were males. All were certified to teach biology.

Ethical Issues

The participants of the "Do It" course had signed informed consent releases when they began the course. Students were assured that their identities would be kept private with pseudonyms used in research reports.

Data Collection and Analysis

The two processes of data collection and data analysis merge; therefore, they will be discussed together. In qualitative research, data is analyzed while it is being collected. Glaser and Strauss (1968) describe a method of comparative analysis in which questions and objectives are refined at various points during data collection. After several participants have been interviewed and the results analyzed the researcher can make comparisons between participants. These comparisons can in turn be used to better direct further interviews and analysis. The discussion guide, interview process, and analytical methods will be discussed in this section.

Discussion Guide

Purpose of a Guide

The discussion guide is a list of questions that are designed to allow the researcher to gather information regarding the overall research question(s) (Maxwell, 1996; Taylor & Bogdan, 1984). According to Patton (1990), the questions in an interview guide provide a framework that can allow the interviewer to explore, probe, and illuminate specific topics. Using the guide as a focus, the interviewer is free to develop questions that emerge spontaneously from the discussion with the participant. The sequence of questions may vary depending on the respondent's answers.

How the Initial Guide was Structured.

Originally, the discussion guide was based on suggestions/requests from Dr. Melear. Melear wanted to know how the course affected the participants and if the course had influenced and/or prepared them for teaching for inquiry, if at all. She wanted to know how they compared the course to other courses they had as students at the university. This guide was used for the seven interviews that were completed in the Fall semester of 2000.

Revisions to the Guide.

The original discussion guide was revised as the first author became more familiar with interviewing (See Appendix). Most of the questions remained the same; however, questions were rearranged and several new ones were added. One interview was conducted using this revised guide.

Suggestions from McCracken (1988) were used to revise the initial guide. The first questions of the interview guide should be structured to put the respondent at ease and to help establish rapport. These questions should be biographical and allow the participant to describe his/her life freely (See Appendix; questions 1-4). Following the biographical information there should be a list of questions that request an overview of particular matters of interest, called grand-tour questions (See Appendix; questions 5-9). The interviewer's responsibility is to listen carefully to the respondent's words and remember phrases and situations that can be probed for further information. The guide used in this study began with biographical questions, followed by several grand-tour questions with probes that asked respondents to describe the "Do It" course, and concluded with several questions that asked how they have applied the course to their teaching. McCracken strongly suggests that questions should be open-ended and allow the participants to respond freely using their own terms (See Appendix; question 1, 4, 6).

Interview Process

Each interview was conducted at a place and time that was convenient for the participant. Each participant was informed prior to the interview that the conversation would be audio-taped. The length of the interviews ranged from 25-40 minutes. Each interview was transcribed from the tape.

Allowing the participant to choose a time and place helped create a comfortable atmosphere because it gave the participant some control of the situation. The interview that was conducted with the eighth participant and the instructor of the course most accurately followed appropriate interview conditions because of author training.

Analysis

The process of analyzing the data for this research project included arranging the interview transcripts in a way that helped increase understanding of them and allowed for the presentation of findings to others. Bogdan and Biklen (1992) describe two approaches to data analysis: one in which data analysis is concurrent with collection and the other in which data analysis occurs after collection. They suggest that beginning researchers should complete some analysis during collection periods but that most analysis should be completed after data collection is complete. As a beginning researcher the first author followed their advice. The types of analysis that Suters completed during data collection included revising the interview guide to help develop rapport with the respondents and to improve it's quality as a means for providing answers to the research questions. She wrote memos, or short notes about what she learned from the interviews. Memos were also helpful in organizing her thoughts concerning the literature on the research topic and about qualitative research in general.

Analysis after Data Collection

Suters followed a method of analysis suggested by Bodgan and Biklen (1992). They consider analysis to be a process of data reduction. The first step was to number the lines of each interview transcript sequentially and to read over them several times. A preliminary list of coding categories was developed from the transcripts by looking for regularities and patterns. Preliminary codes were limited and refined to a final list of codes. The final codes were assigned

numbers and matched to particular pieces of data within transcripts. Suters used a different colored pencil for each category code to mark the transcripts. Once the transcripts were marked with different categories, she copied and pasted sections of the transcripts within *Microsoft Word '97* to make lists of all instances found for each individual coding category.

Suters chose to develop coding categories based on what Bodgan and Biklen (1992) call preassigned codes. These are codes that are used when a researcher is asked to explore particular aspects of the participant's views. The following list of codes were used to help sort the data: Teacher's view(s) of:

1. self as teacher
2. his/her students as learners
3. learning by inquiry
4. how they were changed by the "Do It" course
5. teaching with inquiry
6. nature of science and how it was changed by the "Do It" course
7. other courses compared to the "Do It" course
8. changes that should be made in college courses

Patterns were examined between participants for each coding category. These patterns were used to combine the coding categories based upon similarities between them and to form assertions (See Table 1 for assertions). Code one and two were combined to form assertion one. Code five formed assertion two. Code three and parts of code four and eight formed assertion three. Code six, seven, and parts of four and eight were used to form assertion four. These assertions are described within the "Results" section of this paper. Instances that did not

conform to the theory are reported. Several quotes from the interview with Hickok were used to support the assertions that were revealed by the "Do It" participant interviews.

Validity

Maxwell (1996) proposes several questions that address the validity of research design.

> How might you be wrong? What are the plausible alternative explanations and validity threats to the potential conclusions of your study, and how will you deal with these? How do the data that you have, or that you could collect, support or challenge your ideas about what's going on? Why should we believe your results? (pp. 4-5)

These questions are addressed in this section of the paper. The issue of generalizability is also addressed.

Table 1
Assertions with Representative Examples

1. These teachers expressed student-centered views of their teaching; however, several presented dilemmas with teaching by inquiry.	I don't want to say non-traditional, but I kind of bring everything to life. Not that we necessarily do tons and tons of inquiry, but we do hands-on or involvement things. You know we get up and dance out a process or we get up and play "Red Rover" to illustrate osmosis or something like that. So, we involve ourselves somehow directly in the process. . . . . These kids that I'm teaching, my kids would not tolerate being frustrated that long. They would quit and you couldn't get back into it. So, it might take a little more leading and a little more prompting to really keep the motivation up. **(#3)*** Um, I believe that they learn best when they are engaged in the learning themselves with me just being the facilitator rather than just the lecturer. They always seem to do better if they can just discover things on their own. And um, they will always retain that information better than if I just get up there and give it to them on the overhead projector or something like that. So um, I think the students learn best when they discover things on their own and they're actually doing hands-on things on their own. (#8)
2. These teachers had varied comfort levels concerning their abilities to teach by inquiry.	Now when I teach, one thing that I do is I bring in aquarium tubing and bb's and let kids build a roller coaster. And I say, OK figure it out how to make the bb stop at the end of the tubing. . . .You know, you can't help them and they just have to kind of learn it on their own and they get frustrated. You know when they finally figure it out it's neat to watch. (#1) I guess the hardest part is knowing what kind of activities, hands-on, can I use to get them to learn this topic. If I have a curriculum that I have to use and I have to cover so much in a semester, how do I know at what point can I do inquiry? (#2)

3. These teachers had never used complete inquiry before in connection with a science course; they initially found inquiry frustrating, but they learned techniques, concepts, and the processes of science.	I understood the point about a month after I took the course. I learned about… they said doing science actually learning by doing, actually learning by thinking. I suppose one thing I got from the course was learning how to think scientifically. (#5) And I also think it taught me actually how to design an experiment. Before that I had taken science classes and everything and lab classes like genetics lab and stuff like that. We had to follow a cookbook recipe and I was never actually allowed to design my own experiment. So I think it gave me a chance to see what a scientist actually does. How, you know, to design an experiment. (#6)
4. These teachers' views of the nature of science were changed by the "Do It" course by helping them learn how to design and conduct an experiment and by learning that mistakes are a natural part of science.	But I learned more about how to set up a controlled experiment and in all four years of college, I didn't ever do that. I didn't even do it in high school. That's one thing that I'm making sure to teach my students, what's a variable, what's a constant, what's an independent variable, what's a dependent variable, what's a hypothesis, when do you state the problem, what's the steps, when do you publish data, when do you analyze your results? (#2) It was probably the best class I took as an undergrad. **What made it different from other courses that made it better?** Oh, so many things, because it was unlike any course I'd ever taken. Even you know, you take your science classes with labs that every lab you go into there's at least 30 people in the lab. You're just kind of following directions, reading step by step what you're doing. And this was neat because we had 2 professors in there with just 7 of us. So it was my first opportunity to have kind of a one-on-one relationship with one of my teachers whom, I have had him before and that made it more interesting because I knew him you know as a lecturer, and then to see him in that setting was really neat for me. And like I said the whole scientific process…like you learn the scientific method but you don't ever really use it. So this was actually an opportunity…you know we were creating our own hypotheses and we were running the experiments and then going back and analyzing our results and then changing our hypotheses and then changing our experiments and that kind of thing. So it was actually an opportunity to do science. (#8)

*(# __) – Corresponds to interview participant

Discrepant data has been included as part of the results. Verbatim transcripts were used to insure that there was data to support assertions about the participants' views in their own words. These are called emic descriptions or rich data (Maxwell, 1996). It is possible to avoid misinterpreting the participants' constructed meanings by using the participants' exact wording.

Maxwell (1996) states that "what an informant says is always a function of the interviewer in an interview situation" (p. 91). Therefore, in order to collect information that truly

reflected the understandings of the participants, leading questions were avoided. The discussion guide was helpful in doing this because open-ended questions were used.

The first author explored how she felt about this research topic and her personal experiences related to the topic of science education and scientific inquiry. In reviewing her "cultural categories" she felt she would be better prepared as a teacher as well as more scientifically literate if she had participated in a research experience as part of her teacher education program at the University of Tennessee. This bias could be considered a potential threat to the results; however, Suters' personal opinion was not imposed on the participants' data. The use of the verbatim transcriptions and the discrepant evidence were ways to accurately represent the feelings/opinions of each participant.

Triangulation was attempted to help validate the data. Eight participants were interviewed and therefore eight different perspectives were available. The interview with Dr. Hickok also provided another perspective of the students and the course.

Generalizablity

The results of this study can have external generalizability or have "generalizability beyond (that) setting or group" (Maxwell, 1996, p. 97). Maxwell states that "the generalizability of qualitative studies usually is based, not on explicit sampling of some defined population to which the results can be extended but on the development of a theory that can be extended to other cases" (p. 97). Therefore, the assertions that are drawn from this proposed study could be used to strengthen science teacher education programs in general.

Results

The findings of this study have been organized around the research questions. Information from the interview with the "Do It" course instructor, Dr. Leslie G. Hickok, has

been used to support the assertions in some cases. The "Do It" course helped some of the students understand how to teach by inquiry; however, due to time constraints, the lack of experience on the part of the student with inquiry and the lack of the teacher's experience teaching, most of these teachers are teaching only small, guided inquiry activities on a regular basis. Based upon participants' responses, their views on some elements of the nature of science seemed to be influenced positively by the "Do It" course. All participants expressed the view that they had never had a course like the "Do It" course before. They felt that it gave them experience with the real processes of science. Four assertions have been identified from the analysis of the collected data. The assertions are described with representative examples in Table 1.

Results concerning question one: Relationship between course and participants' teaching with inquiry

Our first research question was aimed towards discovering if the course helped the participants understand how to teach by inquiry. The first two assertions in Table 1 relate to this question. *Assertion one* is these teachers expressed student-centered views of their teaching; however, several presented dilemmas with teaching by inquiry. They had a strong desire to provide authentic, meaningful activities for their students. They used words such as hands-on, enthusiastic, entertaining, and meaningful to describe their teaching.

Assertion two is these teachers had varied comfort levels concerning their abilities to teach by inquiry. Although the teachers felt that being student-centered was the most appropriate way to teach there were several problems mentioned concerning providing inquiry-based experiences for their students. These problems are listed in Table 2 and some specific examples follow. Participant two was teaching chemistry and physical science (rather than her major, biology) and did not feel comfortable teaching with inquiry. She stated this as follows:

> So, I don't know when and how I can incorporate the inquiry based on the topics that I have to cover. With me not being completely familiar with the material, I feel like I'm going to be discovering just as much as they are.

Table 2
Summary of constraints to teaching inquiry-based science

1. Teacher not familiar with content
2. Frustration on part of student - New way to learn and requires constant motivation
3. Frustration on part of teacher - New way to teach
4. Time consuming - Hard to meet curriculum requirements
5. Hard to find other teachers who are using the inquiry-based style
6. Student safety
7. Being a new teacher

Participant three felt that her students became frustrated and needed constant motivation to complete inquiry-based lessons. Participant four found it difficult to teach what she called "full-complete inquiry" due to trying to fulfill curriculum requirements and therefore felt a time constraint. Participant seven mentioned several problems he had with trying to teach using inquiry. He stated:

> Now, I'm still trying to look at people in the real world, real teachers, and compare to them. Not many of them are teaching by inquiry-style . . . I don't use it a lot right now, the inquiry style, because I don't think I really know what I'm doing . . . and just today I had terrible results with that because they became unsafe. In you know, a biology situation, chemistry, and science, I can't have kids working if they're unsafe . . . I think it's a good strategy, it's just that the kids haven't learned that way for 10, 5, however many years they go to school, and I'm a new teacher. So, it's a double whammy.

Frustration seemed to be a common theme concerning inquiry-based learning and teaching. As students in the "Do It" course, these teachers were all frustrated with this new method of learning. They stated that they had never had a course like this one before. As mentioned above, some of these teachers had difficulties teaching their own students in this way. Several stated that their own students were frustrated with inquiry-based teaching. The instructor of the "Do It" course stated:

> How hard it is for me to teach that way I guess surprised me more than anything else. The uh, especially the first two years, maybe it's not so difficult now, the first two years just keeping my mouth shut was so difficult.

Despite the constraints and frustrations mentioned by these teachers the majority of those interviewed are attempting to provide some guided inquiry experiences for their students. Three of the participants stated that they felt comfortable teaching inquiry despite these constraints. Participant one stated:

> At first no, I thought I could never do this. But, you know, after we finished the course, yah, I think it was pretty easy.

Participant five was teaching a course called Introductory Physical Science (IPS) and stated:

> One of the very first activities of the year in my IPS class, which actually is an inquiry-based class, was to give them a box full of stuff and have them come up with science experiments that they could perform, using the box of stuff. I didn't give them very much help at all. I just let them do it and when they did it and wrote it up we talked about it. I offered suggestions on how to make it better. I think that's kind of the same deal as the "Do It" class when they gave me the powder and told me to learn about it.

Participant eight had some reservations about teaching with inquiry but appears to have resolved them. She stated:

> Even after having had the class I was skeptical as to can these kids actually do this. If you give them stuff, can they really make it work and create something um, and do a lab experiment, and I was just not sure. That's what I did my action research project on in my master's program. It was just amazing to see the difference in the class that was doing the inquiry lab experiments versus the class that was doing the cookbook . . . and just retention was just the main thing, because those doing the inquiry remembered um, what the point of the lab was whereas the other kids, it just kind of went in one ear and out the other.

<u>Results concerning research question two and three: Comparison of the "Do It" course to other courses as preparation for teaching science and for understanding the nature of science</u>

The remaining two questions can be best answered in combination. Assertions three and four of Table 1 are restated here to illustrate. *Assertion three* is these teachers had never used complete inquiry before in connection with a science course; they initially found inquiry

frustrating, but they learned techniques, concepts, and the processes of science. *Assertion four* is these teachers' views of the nature of science were changed by the "Do It" course by helping them learn how to design and conduct an experiment and by learning that mistakes are a natural part of science. The examples listed in Table 1 describe the overall view that this course was completely different from any other that these teachers had taken before. A statement by participant one provides an additional view:

> Ok you may have this hypothesis that doesn't work out. But maybe you didn't learn what you thought you would learn but you learned something else by it and how frustrating it can be to mess up. And it's not always, OK here's our idea and we're going to go to the lab and do some experiments and they're going to turn out exactly like we wanted. Because, it's not going to most of the time and you have to say, OK, figure out what you did wrong . . . Sometimes you learn a lot more from your mistakes than you do from like what you initially think you are going to learn.

Hickok, the instructor of the "Do It" course, observed the frustrations the students had with the course. He feels that the way science teachers have traditionally been trained gives them a lot of content knowledge and allows them to teach out of a textbook well. However, in terms of producing the inquiry-kind of teaching there is some deficiency. Furthermore, he stated in an interview with the first author, that even though the students in his course have had biology training they are not prepared for the course. He had taught several of these students before in non-inquiry-based format science courses and felt that they were above average students. Even these students, who he considered to be very bright, who also had high grade-point averages struggled with the design of the course. He stated:

> I was really surprised at their sometimes anger, too. They uh, especially the good book learners, you know the pre-med types, they just wanted to say, cut this baloney out and just tell me what I need to know and I'll know it. . . . So that surprised me, the anger that they had. And in a way, I guess it doesn't because you know, they do, they're successful in the educational system the way it is. And they get angry when you try to do something different with them.

Dr. Hickok feels that the students benefit from the course in two ways. First, they gain an awareness that they have not previously been equipped to do pure experimental science. Second, when they go through the experience of this inquiry-based course, it gives them the confidence to work with some of the equipment and methods of science that they have not had experience with before. In his interview with Suters he stated:

> I think what I'm finding out is that the course provides an opportunity to sort of maybe see what things can be like but in order to really get there it, you know, requires more just digging at it yourself. So by no means do I think we are putting out a finished product with this course even though that was the initial intent.

A statement made by participant eight seems to correlate with Dr. Hickok's statement. Concerning the course, she said:

> I just feel that it really changed my whole perspective on how to teach because growing up and then going through undergrad you have labs spit at you and then you just regurgitate the information back and that's it. And um, it really made me look, I guess it was unique because I was actually the student and I got to see and go through the emotions and feel what it was like you know, to be a part of that and you know actually having a total inquiry-based course. And it just really changed me as far as I would have never taught the way I teach now if I hadn't had that.

This participant also felt that fellow students that she met as an intern who hadn't had the course were missing out. If inquiry was discussed or attempted in their science methods courses those students who had not completed the "Do It" course seemed to not understand fully what was being discussed.

Discussion

During a teacher's first year many of the responsibilities of teaching can be overwhelming and can prevent a science teacher from using student-centered styles advocated by most pre-service science teacher education programs. In addition, teachers appear to be imprinted by the end of the first year of teaching. They continue to teach in the way that they

taught in their first year. However, one way to help new science teachers institute student-centered, inquiry practices in their classroom is to ask them to reflect upon their pre-service preparation program (Adams & Krockover, 1999). This reflection can help them remember what they learned and practiced as part of teacher preparation programs and in some cases help them change their teaching practices. Providing support and transition activities for these new teachers is something for which universities should be prepared.

Duggan-Haas (1998a) stated that research experiences for science education students can often change the world view of those who complete them or "trigger an epiphany about the nature of science" (p. 6). Changes in a person's world-view can be understood best from the participant's own descriptive words. The teachers in this study expressed the desire to teach using student-centered styles which include using inquiry-based methods. Possibly these interviews had the added benefit of helping the new teachers reflect upon their educational preparation in these critical first few years of their teaching, where reflection can help them change their teaching practices if necessary. Patton (1990) states that although the goal of interviews is to gather information, "the process of being taken through a directed, reflective process affects the persons being interviewed and leaves them knowing things about themselves they didn't know...before the interview...(this) can be change-inducing" (pp. 353-354).

The results of this study with these teachers implies that involvement in an inquiry-based course is just a beginning step in the process of preparing teachers to teach using inquiry. The course has helped these teachers become more scientifically literate by involving them in the actual processes used by scientists. However, the ability to teach using these methods has been shown to be challenging. When these teachers do not have others in their own school who teach

using inquiry, or people they can talk to as they could in their pre-service preparation program, their ability to develop skills teaching with inquiry is hampered.

Recommendations

The implications for new science teachers as well as those that are experienced are that they need to work together to try to break the traditional cycle of teaching science through predominately a lecture-based classroom towards an inquiry-based classroom. There should be a consistent trend within schools in which most science teachers teach with inquiry. The teachers in this study experienced the same feelings of frustration in the "Do It" course that they are seeing exhibited by their students when they teach using inquiry. These teachers also expressed that after becoming accustomed to asking their own questions and seeking the answers to them, they enjoyed the class. When students are given many opportunities to learn with inquiry, as the research participants did, they may learn to enjoy the method as well.

Other suggestions to encourage classroom science teachers to implement inquiry-based activities include participation in professional development activities. Teachers who have used the method successfully who share their ideas through workshops or publications can influence other teachers to try the method. Science teachers should also be encouraged to continue their own education. There are many internet-based courses as well as courses offered at local universities which teachers can participate in to strengthen and/or update their skills. As knowledge of the successes and failures of inquiry-based methods is made public, science teachers can develop plans to implement activities accordingly.

Conclusions

In summary, this study has used qualitative research methods to explore the views held by its participants of the longitudinal effects of an inquiry-based research experience. By placing

pre-service science teachers in a situation in which they are required to design their own research experiments, they are given an opportunity to learn in a way that promotes scientific literacy. One of the purposes of this study was to see if these teachers feel more comfortable with implementing inquiry-based learning experiences within their own classrooms. Since the impact of pre-service education programs may not be evident until teachers have been teaching two or three years, or more this type of longitudinal research can be very helpful in determining the effectiveness of teacher education programs. It is possible that results of this intervention may not be detectable until four years of teaching.

The results of this study can contribute to the quality of the science teacher education program at the University of Tennessee. Theory that is developed from the results, for example the assertions that have been made about these teachers, can be used to help develop programs like this at the University of Tennessee as well as other universities. These teachers appear to be very enthusiastic about the course and about what it has done for them personally and professionally, even though more have demonstrated that the objective of how to teach by inquiry has not been attained yet.

As a nation, it has been shown that science skills and knowledge are lacking. We have a great deal of improvements to make in our educational system. A course, such as the "Do It" course, is just the beginning. Ideally, students need to start learning science by inquiry in elementary school. Science education is sometimes omitted or pushed aside in order to emphasize reading and writing. The emphasis on science learning by inquiry should be continued then throughout the child's education. Questions that arise from this study include:

1. What are some ways to help new science teachers overcome the obstacles of beginning teaching and use inquiry-based teaching as part of their repertoire?

2. What can universities do to provide support and transition activities for new science educators?

3. Would providing a course such as the "Do It" course to elementary educators help improve elementary science education?

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Appendix

Interview questions with probes for "Teaching Science-Just Do It" course

1. Tell me a little about yourself.	▪ What and where do you teach?
2. How would you describe yourself as a classroom teacher?	
3. How do you believe your students learn best?	
4. What is the meaning of the nature of science to you?	
5. When did you take the "Teaching Science? Just Do It" course	▪ At what point in your college career did you take the course? ▪ How long have you been teaching since you have taken the course?
6. Describe what the "Do It" course was like.	▪ What was your initial reaction to the course? ▪ Did your reactions to the course change over the time that you were taking it? How? Or how not? ▪ What were the expectations of the instructor? ▪ What did you do during the course? ▪ Does the title of the course have any meaning to you?
7. Had you experienced a course like this one before? Have you experienced a course like this one since then?	▪ Explain
8. Did the course prepare you in any way for teaching?	▪ Did the experiences you had with inquiry in the course help you understand how to teach by inquiry? How or how not? ▪ Did you learn any new concepts about how to learn science from this course? If so, what were they? (Possibly inquiry) Do you try to use them with your students?
9. While you were taking the course, did you feel that you could teach students in the way that the course was taught?	▪ How do you feel now?
10. How does this course compare to other	▪ Teacher methods courses or pure

courses you had as an undergraduate or graduate student in preparing you to teach?	science courses
11. After experiencing __ years of teaching, what changes would you suggest professors make in their courses to make their courses more meaningful and useful for you?	▪ Teacher methods courses or pure science courses
12. Did the "Just Do It" course help you understand science?	▪ Did you learn anything new to you? If so what? (Anything from equipment use to concepts) ▪ Did you feel that the structure of the course helped you understand the nature of science?
13. Would you recommend the course be required of future biology teachers?	▪ If so, are there any changes you would recommend?